NOAA FISHERIES
Alaska Fisheries Science Center

Science behind Sustainable Seafood Module

Lesson 2: Population Estimation

Brief Overview

Grab your fishing gear and take your class fishing with this mock scientific survey of the Bering Sea in Alaska. Learn the basics of estimating population of animals that move around and are basically invisible to us landlubbers. This lesson provides a tabletop activity that is a mock scientific survey where students discover the challenges faced with trying to count fish in the ocean, learn how fishery scientists use basic math skills and simple statistics to estimate abundance of fish species in Alaska using a real world scenario. Results from this activity will be compared to real population data for the Alaska Walleye pollock. This activity will take one 50 minute period to complete.

How many fish are there?

A goal of fishery science is to determine the amount of fish to harvest that does little to no harm to the environment and leaves enough fish in the water for the population to renew itself. The first step is to find out how many fish are in a population. Pete pollock has offered her species as an example. What do we know about walleye pollock? We know they live in the Bering Sea off Alaska.

What challenges do you think the scientist will face in trying to count pollock?

- The ocean is huge – it covers about 70% of the Earth
- Much of the ocean is dark
- The parts of the ocean that pollock live in are very cold.
- There are about 5 billion pollock in the Bering Sea.
- Pollock are always moving around!

Just knowing these facts, it is clear that a scientist isn't going to be able to count every fish.

How do scientists figure out how many pollock are in the ocean?

Fisheries scientists estimate population size from samples. It would be really expensive and inefficient use of time to sample the entire ocean, so scientists use different sampling methods, depending on species and geographic location, to estimate population size. For instance, to sample for pollock in the Bering Sea, scientists put an imaginary grid over the entire continental shelf and only sample a few of the grids. How do scientists select which grids to sample? One way is to use a random sampling method. This method ensures that areas with fish and without fish are represented. If scientists sampled only where there were a lot of pollock, their estimate would be biased. Their estimate would be higher than the actual population size. If a harvest level were based on that estimate, we would end up depleting the pollock population.

Big Ideas: Populations can be estimated without counting every fish.
Essential Question: Why is it important to estimate population size in fisheries?
Objectives: The learner will be able to estimate and explain sampling methods used to determine population size of Pollock (a commercially important species) while increasing problem solving skills.

Key Subjects/Standards

Science, Math, Economics, Social Sciences, History/Social Science,

National	Science: NS.9-12.1 Science as Inquiry. NS 9-12.3 Life Science: Interdependence of organisms, Behavior of organisms. NS 9-12.6 Personal and Social Perspective: Population growth, Natural resources, environmental quality. Math: NM-NUM. 9-12.3 Number and Operations: compute fluently and make reasonable estimates. NM-PROB.CONN.PK – 12.3 Connections: recognize and apply mathematics in contexts outside of mathematics. Economics: NSS-EC.9.12 Scarcity. NSS-EC.9-12.4 Role of incentives. Social Sciences: NSS-G.K-12.2 Places and Regions. NSS-G.K-12.3 Physical Systems.
Ocean Literacy	6. The ocean and humans are inextricably interconnected (b, c, e, g).

Teacher Preparation

1. Read the entire activity and review all background material and resources.
2. Go through Fish Fetch online tutorial.
3. Determine the amount of time you would like to dedicate to this activity. If classroom time is readily available, a minimum of two 50-minute classroom periods is advised. If classroom time is limited, students may complete some of their tasks as homework.
4. Determine the best assessment strategy for your class based on suggestions made by authors.

Materials List

- 2 - 4' x 6' sheets of butcher paper or canvas. Students will draw the eastern coast of the Bering Sea and the 50 m, 100 m and 200 m bathymetry lines. One sheet, which will go on the top, will have grids with holes in each grid to sample. A map of the Bering sea is provided in JPG format.
- Clipboards for each team.
- Tally counter for each team.
- 100-1000 paper clips or wood fish beads other small, flat-sided objects that imitate fish.
- 5 objects with a flat bottom to toss onto Bering Sea, such as a bean bag or large dice.
- Random number table.

Background

Importance of estimating population size

Estimating population size is something scientists and government officials have been trying to do for centuries. Our very own U.S. census began in 1902, but there were attempts prior to that to estimate population size.
As we know not everyone in the U.S. gets counted and the U.S Census department is always modifying how it collects data. Knowing how big a population is important for knowing things like how many hospitals our country may need and where to put them, but what about changes in population size. It is also important to know if the U.S population is growing, shrinking or stable, this will give our government an opportunity to plan for the future.

In the wild, estimation techniques such as line transect, aerial surveys, tagging animals or simple observations over time. It is important to document how population estimates were derived to determine the uncertainty around any values that are given. Knowledge about the population dynamics is also critical, do they migrate or are they stationary, do juveniles and adults co-occur or do they have different habitats?
Is it good science to count the number of ducks in one lake and then extrapolate the observed trend to the entire population? Not really, although that trend can be used to make hypotheses about what may be happening to the population as a whole, but more science would need to be done to get a better understanding of what may be happening, in a sense, to get the entire picture and not just a part of it.

Challenges with estimating populations that live in the ocean

It covers 70% of the earth, and contains countless different habitats. Even in the open ocean the difference in sunlight and temperature between the surface and 500 hundred feet deep is enough to make different habitats for certain species. Some animals like it warm and sunny at the surface but others like it cold and dark where it's deeper. Getting to these deeper habitats presents another problem; we humans can't breathe water, although there is SCUBA, we are limited on how deep we can dive because water is heavy.

Physics of water

At sea level you have one atmosphere of air pressure weighing on you, air is heavy though you may not realize it because you're used to it. Think about when you swim to the bottom of a pool, you may feel a squeeze in your ears. That's the weight of the water creating pressure. Under 33 feet of water, you have twice as much pressure on you than at the surface, at 66 feet, there's 3 times the pressure. Considering that the average depth of the ocean is 12430 feet, there's a lot of water we can't easily reach. Think about any air in our body getting squeezed, your lungs would be the size of lemons! You couldn't take a breath even if you had SCUBA. To go deeper we need special vehicles and equipment which can be very complicated and costly. So the depth of the ocean creates a serious challenge when we wish to estimate animal populations in the ocean.

Habitat features - population density

The ocean has many diverse habitat types. Some are determine by geologic features from sandy beaches and rocky shores along the land/water interface, down to canyons, abyssal planes, rocky outcroppings, sea mounts or pinnacles and deep trenches. Other habitat types are determined by other organisms such as coral reefs or kelp forests. Another habitat type is the coarseness of the sediment along the ocean bottom, from fine silts and mud to coarse sands and boulders. Certain fish species may have strong associations to a geologic habitat type, such as shortraker rockfish whose populations are strongly correlated with boulders or some fish may a strong association with oceanographic structure such as where cold nutrient rich bottom water meets the surface waters to create a feast for phytoplankton and zooplankton and an environment rich with marine life that eats them. Fish populations may school in dense aggregations associated with these upwelling areas or fronts, or above rocky outcroppings, while other fish populations may have a uniform distribution across a habitat such as yellowfin sole across the muddy bottom areas of the Bering Sea. What happens if we sample a large area with multiple habitat types and then extrapolate our sample to the entire area? We may be overestimating the population size. The density of a population may not be uniform throughout the area - density is # of x divided by the area sampled.

Known features of the Alaska Walleye Pollock population

Walleye pollock (*Theragra chalcogramma*; hereafter referred to as pollock) are broadly distributed throughout the North Pacific with the largest concentrations found in the Eastern Bering Sea. Also marketed under the name Alaska pollock, this species continues to represent over 40% of the global whitefish production with the market disposition split fairly evenly between fillets, whole (headed and gutted), and surimi. An important component of the commercial production is the sale of roe from pre-spawning pollock. Pollock are considered to be a relatively fast growing and short-lived species. They play an important role in the Bering Sea ecosystem.

In the U.S. portion of the Bering Sea three stocks of pollock are identified for management purposes. These are: Eastern Bering Sea which consists of pollock occurring on the Eastern Bering Sea shelf from Unimak Pass to the U.S.-Russia Convention line; the Aleutian Islands Region encompassing the Aleutian Islands shelf region from 170°W to the U.S.-Russia Convention line; and the Central Bering Sea—Bogoslof Island pollock. These three management stocks undoubtedly have some degree of exchange. The Bogoslof stock forms a distinct spawning aggregation that has some connection with the deep water region of the Aleutian Basin (Hinckley 1987). In the Russian EEZ, pollock are considered to form two stocks, a western Bering Sea stock centered in the Gulf of Olyutorski, and a northern stock located along the Navarin shelf from 171°E to the U.S.- Russia Convention line (Kotenev and Glubokov 2007). There is some indication (based on NMFS surveys) that the fish in the northern region may be a mixture of eastern and western Bering Sea pollock with the former predominant. Bailey et al. (1999) present a thorough review of population structure of pollock throughout the north Pacific region. Genetic differentiation using microsatellite methods suggest that populations from across the North Pacific Ocean and Bering Sea were similar. However, weak differences were significant on large geographical scales and conform to an isolation-by-distance pattern (O'Reilly et al. 2004; Canino et al. 2005; Grant et al. 2010). Bacheler et al. (2010) analyzed 19 years of egg and larval distribution data for the eastern Bering Sea. Their results suggested that pollock spawn in two pulses spanning 4-6 weeks in late February then again in mid-late April. Their data also suggests three unique areas of egg concentrations with the region north of Unimak Island and the Alaska Peninsula being the most concentrated. Such syntheses of egg and larval distribution data provide a useful baseline for comparing trends in the distribution of pre-spawning pollock. Check out fact sheet about Pollock.

Instructional Strategies/Procedures

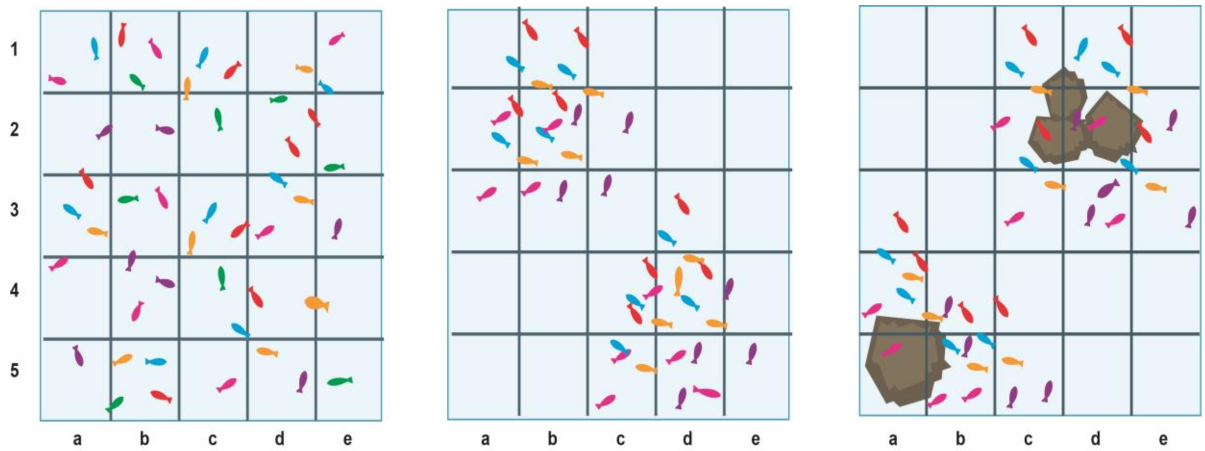
Exploration

- Go over the basics to why we have to estimate populations, in general and especially in the ocean. Have students explore the introduction to population estimation presentation online at the NOAA Alaska Fisheries Science Center education website.

Engagement

Play Fish Fetch! A survey simulation activity!

1. Create 3-4 groups (vessels) of students to form a fleet of research survey vessels. Depending on the number of students per group give the students the following roles (minimum roles are record keeper, sampler (or person(s) who tosses object or determines location to sample based on random sample table) and counter.):
    a. Field Party Chief – oversees operations and determines where to sample using random sample table. FPC informs Deck Boss of their decisions.
    b. Deck Boss – selects sampling method and tool tells fish sampler where to sample.
    c. The Fish sampler will collect sample from grid and inform data recorder.
    d. The Data recorder has a clipboard with a printed data sheet to fill in.
    e. The Data analyst will make final calculations of population estimate and ensure that the data recorder is doing their job well.
2. Using two sheets of butcher paper, one as the ocean floor and the other as the ocean surface with a grid painted over the ocean (10 x 10 is easiest, equal size squares). Distribute known number of paperclip "fish" across the bottom. Try these different distribution patterns that simulate:
    a. uniform distribution,
    b. clumped distribution and
    c. distribution associated with habitat



3. Have the sampler of each group randomly toss their sampling gear (bean bag, die or coin) onto the grid to find out which grid to sample.
4. The counter will go to grid closest to the sampling tool and count the fish under the flap.
5. The recorder records the data onto their boats' data sheet.
6. Have the students do this type of sampling four more times.
7. Recorder now finds the average number of fish per sample.
8. Ask the students how they can find out how many fish are in the total area (answer: multiply the average number of fish per square by the total number of squares).
9. Have teams share their estimates of abundance.
10. Take off the top sheet of the butcher paper and see where the fish populations really are. Have a discussion about sampling strategies students can use to better assess the entire populations.
11. **Random sampling introduction.** Depending on the size of your area being sampled and the number of grids, use the RAND function in Excel to get five randomly generated numbers. For example, if you have 100 grids, the function will be =RAND()*100, you can format the cells so that the number is a whole number.
12. Using the random number generator in excel have students create a survey plan for the survey area. The total number of cells to sample is five. (create survey plan worksheet?)
13. Have teams collect their data – no tossing required.
14. Have them estimate abundance similar to the above method and compare answers.
    a. Did the random sampling method give better results?
    b. Talk about bias and unbiased sampling
    c. Discuss how error may enter sampling methodology
    d. How would the students account for uncertainty in how many fish are actually out there?
    e. Why are zeros important? Why not find out how many fish are where fishermen historically fish?

Look at real data

1. Using the data from the EBS pollock stock assessment on page 38 in table 1.10. Graph the biomass over the years.
    a. What has the pollock population done over the years? Has it been stable?
    b. What is the average number of pollock in the EBS over the survey years available?
    c. Review the 2006 survey cruise report to find out how many samples are taken and what kind of data are collected by the survey.

Other options for the game:

1. Give each team a budget of $150,000 to conduct their survey.

2. Each day of sampling costs $10,000
3. One sample can happen in one day
4. Create challenge cards with the following challenges:
    a. Net gets ripped – Lose ½ day – minus $5,000
    b. Big Boss found money – Budget increases by $5K
    c. Storms at Sea – Lose 1 day – minus $10,000
    d. Budget Cut – Lose $50,000
    e. Storms at Sea – Lose 2 days – minus $20,000
    f. Big Boss found money – Budget increases $10,000
    g. Net catches large boulder – Lose 1 day trying to get it off the ship – minus $10,000
    h. Left crew on dock need to go back and get them – Lose 2 days – minus $20,000
5. To begin survey – pick a card.
6. Recalculate budget.
7. Use same sample design as above, but pick card after every 3 days or samples.
8. Remember to subtract $10K for each day of the survey.
9. After card is picked recalculate budget.
10. Keep samplings until $10K is left. This is needed to get back to shore.

Extensions & Connections

Extension 1:

Read following scientific paper about how scientists estimate shark populations. Have students give a summary of the challenges the scientists faced and what they finally came up with to estimate shark population.

Extension 2:

Do fish populations move with changing temperature?

1. Check out the data visualization map of all the bottom trawl survey data collected by the Alaska Fisheries Science Center since 1982. http://www.afsc.noaa.gov/RACE/groundfish/survey_data/default.htm
2. Select the group - Gadiformes, then the species, Walleye Pollock. Then select catch>50 KG/HA (kilograms/ hectare). Drag the timeline button to 1982 and press the play button to see where scientists found these medium sized pollock catches. The different colors in the background are bottom temperature collected during the same survey. Click on the legend to find out what temperatures adult pollock like or don't like.
3. Write about your findings. Do pollock populations change with respect to bottom temperature?
4. Follow the same instructions using a different fish species. What conclusions can you come up with?

Assessment

Run through game once:

1. Ask students to develop hypothesis using random sampling design – How will sampling design change results?

Run second time with changes:

1. Mini lab write up – individual write up – 2 paragraphs –Title, Purpose, Methods, Results, Conclusion including graphs and diagrams.
2. Participation in group activity – peer assessment?

3. Reflection – explain what they learned about population estimation, not just the numbers.

Vocabulary: Uncertainty, estimation, population, selectivity, habitat, individual, sampling, Pollock, fishery, bycatch, transects, random numbers, surveys, variation, statistics, tow, bottom trawl, mid-water trawl, hydroacoustics, water column, mean (average), overfishing level (OFL), allowable biological catch (ABC).

Possible Misconceptions

Bottom trawling is bad.
Oceans are overfished.
Fishers are bad.

Reflection on Roles – Preparation for Lesson 6

Have students break up into their groups – Industry, scientists, concerned citizens and council members. Have them reflect on what today's lesson may be relevant to their supporting statements they will be giving to the council members. Council members can reflect on what they would expect to see from each group.

Resources for Teachers

- Fish Fetch online tutorial
- For other methods used for estimating population size use this lesson at National Geographic education - Fish Tagging and monitoring
- Mapping the ocean floor and fish habitats http://www.watchknowlearn.org/Video.aspx?VideoID=33302
- Teacher @ Sea explores pollock hydroacoustic survey http://www.nmfs.noaa.gov/stories/2012/10/10_17_12teacher_at_sea_pollock.html

For more information and questions:

Contact the Alaska Fisheries Science Center Education Team
Website: http://www.afsc.noaa.gov/education/
Email: afsc.outreach@noaa.gov